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ABSTRACT

Definitions of biosphere and ecosystem are provided as the basis for understanding a problem that threatens to become (or already is) a global issue, namely, human activity which results in reducing the diversity of life forms present in the biosphere as an ecosystem. Two aspects of this problem are: (1) the growth of human populations worldwide crowding out other species as they are overcome in the resulting competition for space and food; and (2) the practice of eugenics, which has worked to reduce individual variation that exists within a species. Although there have been efforts to counteract the general reduction of genetic variabilty in domestic plants and animals, these efforts are small and slight at best. The greatest loss of genetic material is now going on in tropical rainforests, which are being cut by commercial loggers and cleared for farms and ranches at an alarming rate. The reasons for and consequences of this practice are addressed, as well as implications for all living things. The loss of the biosphere's genetic variability (as illustrated by the examples in this paper) transcends national boundaries and requires policy action on the part of all concerned parties to resolve the problem. (JN)

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THE LOSS OF GENETIC DIVERSITY: AN IMPENDING GLOBAL ISSUE

by

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Perhaps the most striking visual image of the last twenty-five years is that found in the sattelite photographs of the Earth. These images, especially that done by NASA in 1968 that appeared on the cover of The Last Whole Earth Catalogue brought home the beauty, finiteness and fragility of our home. The space photographs show the planet as it is, an integrated, interdependent whole, rather than as people would like to view it on their maps--divided by political boundaries into areas which one group or another tries to control and exploit.

Our interdependent earth can be described as an ecosystem defined by Odum as, "any entity or natural unit that includes living and nonliving parts interacting to produce a stable system in which the exchange of materials (matter, not energy) between the living and nonliving parts follows circular paths."[1] Environmental scientists commonly emphasize two points about ecosystems. First, changes in one part of an ecosystem may have profound effects on other parts of the system. These effects can be understood and coped with only if we analyze the system as a whole and take the time necessary to understand the interrelationships that exist in the system. Second, the more diverse an ecosystem, the more stable, resistant to disruption, and adaptable it is. This suggests that the more varieties and species we find living interdependently as part of a particular ecosystem, the better and stronger that ecosystem will be in the long run: For example, forms of agriculture using several species of plants in the same location is much less vulnerable to crop failure

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[1] Van Nostrand's Scientific Encyclopedia, 5th ed., "Ecology," p. 859.

due to blight or drought than are large areas planted with only one variety of crop.

The Biosphere is the portion of the earth on or in which life exists. It is a shallow surface region, including the land surface and near surface, fresh water, the oceans and that part of the atmosphere known as the ecosphere. The ecosphere is that portion of the atmosphere capable of sustaining life. It reaches from the land and ocean surface to approximately 4 km (2.5 miles) high. It is not inaccurate to refer to the entire biosphere and all its inhabitants as a single, large, extremely complex ecosystem. It also follows that the two points previously emphasized about ecosystems apply also to the biosphere.

These definitions of Biosphere and ecosystem provide the concepts needed to understand a problem that threatens to become a global issue, if it has not become one already. Human activity results in a reduction in the diversity of life forms present in the biosphere as an ecosystem: For example, the conversion of a land region from its wild state into agricultural usage has invariably resulted in a sizeable reduction in the numbers of plant and animal species found in that region. This process probably started with the agricultural revolution, around 10,000 BC, and has been practiced unceasingly right down to the present day.

There are two aspects to the problem of species loss. In the firts place, the growth of human populations worldwide crowds out other species as they are overcome in the resulting competition for space and food. We are probably among the most successful life forms in the biosphere at present. I hesitate to call us the most successful species on Earth, however, because the cockroach, some bacteria, many insects, and even a few fellow vertebrates such as the brown rat,

give us real competition on that score. Nonetheless, our massive increase in population along with exploitative attitudes toward our fellow creatures and our environment has caused, and continues to cause, severe reductions in the numbers of species present in the biosphere. There are many publications in existence that present thorough discussions of the problems of extinction and the endangerment of wild species. I will not try to add to them here. Suffice it to say that each species lost has a negative effect on the biosphere's total stability and adaptability.

A second part of the problem is the practice of eugenics (selective breeding) in both plant and animal agriculture. This has worked to reduce the individual variation that exists within a species which, in the long run, results in reducing that species' adaptability to changing environmental conditions. Farmers since the beginning of agriculture have practiced some form of eugenics and no special knowlege of genetics is really required. One simply allows only those individuals in a species whose physical characteristics are "desireable" to reproduce the next generation. Individuals with "undesireable" characte istics are culled out and the species is considered "strengthened."

The fallacy of this practice lies in the process of deciding what is "desireable" in a species. When humans do this, the goal always seems to be short-term and limited. We confuse our own wants for what is best for the species and the biosphere. We have bred dogs for configuration only, dairy cows for configuration and milk production only, beef cattle for quick weight gain characteristics only, and so the list goes. We have gotten the characteristics we wanted, but we have reduced the adaptability and total strength of each species without exception.

There are many examples of changes in a species due to selective breeding. My father told me that when he was a lad on the farm, between 1915 and 1925, the best hunting dog they ever had was a Standard Poodle. That dog was strong, smart and enduring. He also had an excellent temperament. Those observations describe a greatly different beast from what Poodles now tend to be, thanks to eugenics. Any purebred dairy cow will produce enough milk to feed at least four to six calves while normally giving birth to single calves. Twinning and even triplets sometimes occur, but these are exceptions. This milk producing capacity is, in the natural state, not in the cow's best interest as an individual or a species. A convincing argument for this position is provided by a cow that has not been milked by a human for twenty-four hours while in the first quarter of lactation. The Saint Bernard dog is regarded by most people outside dog breeding circles as a kindly, bumbling creature that is large, but harmless. People who have had recent experience with the breed have learned that many behave like Pit Bulldogs and Dobermann Pinschers are supposed to act. In other words, they are mean, treacherous and dangerous. This, again, has been brought about through the practice of eugenics. In the mid-sixties, one of the breed's grand champion males had a very bad temperament and his genes, or "bloodline," as eugenecists are wont to say, have become very strong in the ancestry of purebred Saint Bernard dogs. This list of genetic changes could continue indefinitely.

The next stage in this practice of systematically reducing a species' genetic variation has gone on mainly in agricultural circles only. I refer here to the practice of reducing the number of varieties, or breeds, within a species. Perhaps the single best example of this lies in animal agriculture with the

widespread adoption of the Holstein-Frisian cow as the dominant dairy breed in Western Europe and North America. The Duroc pig also is the most popular breed of that species. The process has gone so far that some breeds of domestic animals are as much in danger of becoming extinct as the Blue Whale. I refer to breeds such as Chartley Park White cattle which have been in England since the Roman occupation of that island, the Texas Longhorn, many varieties of "obsolete" pigs, at least ten breeds of sheep, and many others. These varieties have, until very recently, simply been allowed to die out or, as in the extreme case of Denmark, "obsolete varieties" were systematically killed. A priceless genetic bank is rapidly disappearing.

With plants, the best example lies with corn, or maize. At present, more than seventy percent of the U.S. corn crop is derived from only six parent lines. This severe restriction of U.S. corn's genetic base has occurred since the 1930's, when hybrid seed corn was first introduced in the U.S. There was a further genetic base reduction in the 1950's with the introduction of the Texas male sterile variety, which reduced production costs significantly.

Another stage in eugenics has been used successfully to date only with plants. Tissue culture is the name given to the process. It is a form of cloning where cuttings of very good specimen of particular plants are started and caused to grow on a large scale basis, giving a large number of genetically identical individuals of the plant species in question. To date this method, for reasons of cost, has been used only with a limited number of species, but plans to expand the practice are very much extant. Again, we see the trend toward monocultures and away from genetic variety wherever human operations on the biosphere come into play. At each stage our skill at this becomes greater.

It should also be pointed out that some efforts have been made to counteract the general reduction of genetic variability in domestic plants and animals, but the efforts are small and slight at best. Concerned British, French, Netherlanders and Austrians are trying to save threatened domestic animals from extinction through the setting up of show farms similar to zoos and trusts. With plants the situation is somewhat better. Most agricultural seeds are bred by seed companies who practice large scale eugenics and are aware of the need for periodic infusions of new genetic material. The U.S. Department of Agriculture has a national plant germ plasm system whose purpose is to preserve a strong genetic base, mainly in the form of seed banks, of all major agricultural plants. However, according to the assessment of the General Accounting Office (GAO) review of the system in 1980, the system "lacks a sense of direction and has no effective centralized management."[2] Furthermore, most seed collections are sadly deficient in wild races of the plants in question.

As a result, the U.S. corn crop is almost as vulnerable as it was in 1970 when 15% of it was lost to a single strain of leaf blight. That happened mainly because the U.S. corn growing industry is essentially a monoculture.

The latest advance in genetic manipulation, ironically, has reawakened interest in genetic variations, wild races and germ plasm preservation. Recombinant DNA work, the transferral of genetic information from one species into another, has taken a few steps beyond the laboratory. Its major successes have, to date, been in the area of pharmaceutical manufacture where, for

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2 Science: Vol. 214, No. 4517, 9 Oct., 1981, p. 161, "Genetic Vulnerability Down On the Farm."

example, bacterial cells have had genetic information transplanted into them that enables them to produce human insulin. However, agriculturalists have been hopeful about recombinant DNA's usefulness in developing new plant strains. For example, the Campbell Soup Company and Heinz, U.S.A. are racing to be the first to develop a "supertomato" with a higher solids yield that present tomatoes give. Their work has led them into the wild uplands of Peru in search of a wild tomatoe that is green, the size of a pea, often poisonous, but with a solids content as high as 13%. It also grows at altitudes of 12,000 feet. These researchers plan to introduce the high solids genes and the high altitude survival genes of this wild cousin into domestic tomatoes to produce a "supertomato" that will make them all rich. In other words, some are beginning to see that genetic loss can be more than an aesthetic problem. Those wild species' genes are necessary as templates for future practical application. This applies especially to food plants and pharmaceuticals. Every antibiotic known was first discovered as a bacterial or yeast waste product--a part of the natural world. Not one was synthesized from scratch. We need those wild genes for models.

The greatest loss of genetic material of all, however, is now going on in the tropical rainforests. They are being cut by commercial loggers and cleared for farms and ranches at an alarming rate. This is a recent development occurring particularly during the last 15 years. The most serious inroads are occurring in South America and New Guinea. Brazil is presently the world's third largest user of biocides. According to Jose Lutzenberger, Brazilian ecologist and agricultural engineer,

> Never in the history of life has there been such a biological holocaust as the one conducted here. Thousands of species disappear per year without anyone noticing. The Universe is poorer for every species that vanishes. Each lifeline in the symphony of evolution is a unique, irreversible historical process that can be cut off, but can never be resumed thereafter. Brazil's practices threathen Life.[3]

On the other hand, Robert Bierregaard and fifteen to twenty other biologists are working in the field trying to determine the best methods to enforce the Brazilian government's edict that fifty percent of the land in the Amazon basin be left in its natural state. Parcel size and shape in the patchwork of cleared and preserved land that will follow this will be important. The idea is to try to preserve as many species as possible.

"When left alone, tropical moist forests like the Amazon excel at supporting genetic diversity. There are probably at least 4.5 million kinds of organisms in the world, of which at least 3 million occur in the tropics."[4] For example, Southeast Asia, smaller than Western Europe, has 25,000 species of flowering plants, about ten percent of the world's floral species. Britain has about 1,430 native plant species. The Malay Peninsula, about one half Britian's size, has 7,900 native plant species. Also, one in five birds and an estimated twenty percent of all higher plant species evolved in the Amazon's lowland forests. One hectare of temperate zone forest normally carries about 10 species of trees. One hectare of tropical forest near Manaus, Brazil carries 235 tree species.

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3 Mother Earth News: No. 70, July/August, 1981, pp. 74-76, "The Rachel Carson of Brazil: Meet an Outspoken Ecologist."

4 Science News: Vol. 118, No. 4, 4 Oct., 1980, pp. 218-219, 221, "Saving the Amazon," by Janet Raloff and Joanne Silberner.

One might be tempted to suggest that the tropical rainforest is the biosphere's genetic laboratory. One can state with validity that the number of species per land surface unit goes down as one moves away from the tropics and the number of individuals per species goes up as one moves in the same direction. All the same, the tropical forests are being cut at an alarming rate. Norman Myers, author of The Sinking Ark and drafter of the National Academy of Science's report "Conversion of Tropical Moist Forests" (1980), suggests that extrapolations from present rates of loss predict elimination of all tropical moist forests within forty years.

This destruction of tropical forests is going on for two purposes: One is to exploit tropical timber, which is one of the third world's fastest growing exports. Its revenues presently rival those from sugar, cotton, or copper. The second reason is to expand agriculture. This is more devastating than logging. Forest farmers' activities constitute the largest factor in the conversion of tropical forest. Ninty percent of the world's human population growth over the next twenty years is expected to occur in the tropics. Thus, the pressure to exploit these rain forests where the population density is now as low as that of the Sahara Desert, will only increase.

Why, aside from aesthetic and humane reasons, do we need to be concerned about the loss of various plant and animal species? Let us start with the short-term pragmatic reasons those primarily of economic concern. Many tropical forest species have benefitted humanity. They supplied the original stock for many food staples; rice, millet, cassava, yams, bananas, pineapple and sugarcane. Countless more await exploitation. In the New Guinea moist forest alone are some 250 different varieties of edible fruit-bearing trees, only 43 of which

have been cultivated. In addition, crossbreeding wild relatives with refined crops offer seed producers and farmers fresh gene plasm. Tropical moist forests are also home to most of the world's drug-yielding plants. For example, rhizomes from one Mexican yam species, which grows only in tropical forests, produce virtually all the world's diosgenin. Diosgenin is used in preparing many hormones, including some used in birth control pills. Diosgenin-based contraceptives are a $700 billion a year industry. More than two hundred sixty South American plants exhibit some degree of contraceptive power. When we also consider that only somewhere between 15 and 50 percent of these species have even been identified and recorded, we can truly say that we are losing far more than we know with the destruction of tropical rainforest.

At a more profound level, the loss of species can signal an early warning to us of future dangers. We must not only be aware of individual species being lost, but also of the underlying causes of these losses and the implications for all life, including ourselves. If, as biologist James Lovelock suggests in The Gaia Hypothesis, the biosphere has modified and continues to modify the terrestrial environment for its own survival, it does so through a very interrelated set of activities involving a great number of different life forms contributing to the process. If, the biosphere's genetic variety continues to be narrowed as it has been during the last 50-100 years, this process could very well be far more threatening to not only humanity but to all life on the Earth than any other prior human activity.

Loss of the biosphere's genetic variability is a rapidly emerging global issue. It has all the generally recognized characteristics of a global issue. It transcends national boundaries and the problem cannot be solved by any con-

cerned agency acting alone. It is just now beginning to take on a present imperative. Rainforests are being cut at an alarming rate, more wild species are threatened with extinction or disappear with each passing day. Human experiments with domestic life forms lead directly, it seems, to the disappearance of vast genetic reserves in the form of traditional food plants and animals. These are replaced with genetically uniform new hybrids that fit present agri-economic fashion. Resolution of the problem requires policy action on the part of all concerned parties. This has not been considered yet. Furthermore, there is far from universal recognition that a problem even exists. Finally, the problem appears to be persistent: It will not go away by itself. I see the reduction of genetic variations as the major emerging global issue of this century's last 15 years.

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